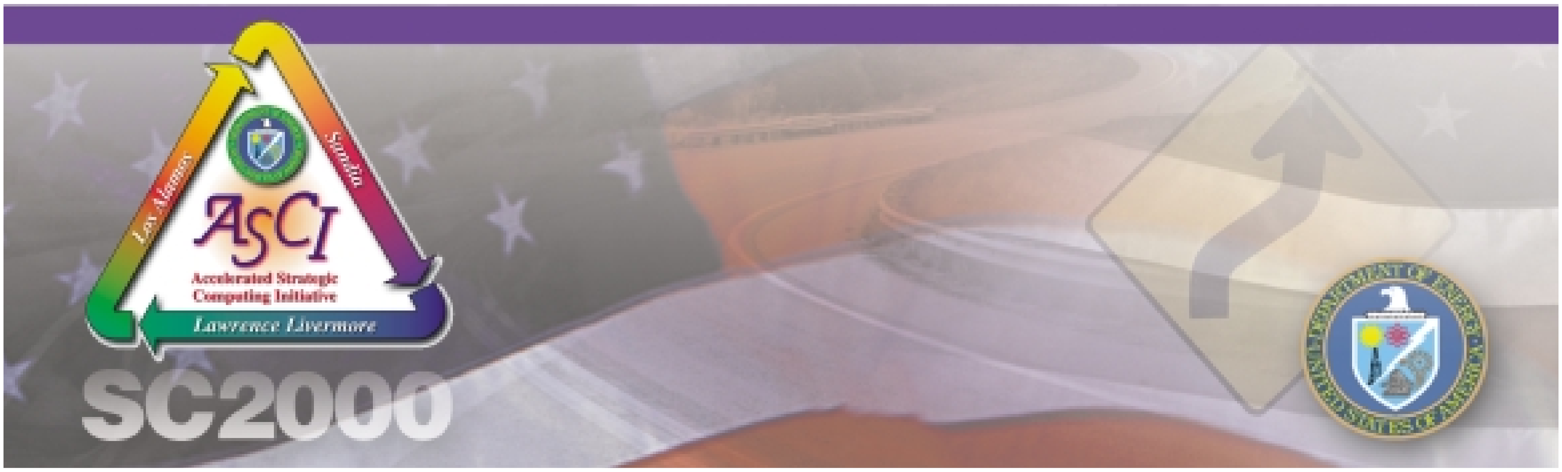



# Virtual Prototyping with Advanced Simulation Tools

## Sandia's DAKOTA Optimizes Computer Models

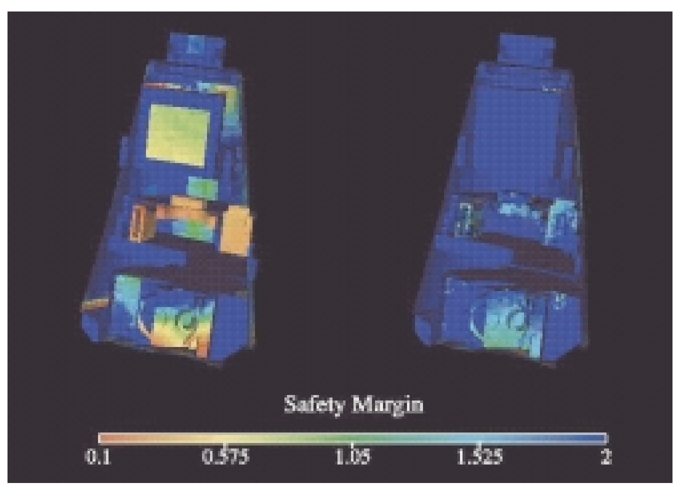
***A powerful software toolkit developed by Sandia National Laboratories is helping weapons designers and analysts answer fundamental engineering questions in support of the U.S. Department of Energy (DOE) stockpile stewardship mission. The toolkit is called DAKOTA, short for Design Analysis Kit for OpTimizAtion.***

DAKOTA was created to leverage Sandia's investments in state-of-the-art modeling and simulation by using simulation tools for more than just single-point solutions. DAKOTA provides a flexible interface between the designer's simulation software and the latest algorithms for optimization, uncertainty quantification, parameter estimation, design of experiments, and sensitivity analysis. This enables the designer to explore a variety of complex engineering and manufacturing issues such as product safety, reliability, vulnerability, and performance. Furthermore, with a significant emphasis on high-performance computing from the DOE Accelerated Strategic Computing Initiative (ASCI), large-scale applications can be tackled quickly so that high-fidelity analyses can impact decisions early in the design cycle.

DAKOTA has been interfaced with over 20 simulation programs, including SALINAS (structural dynamics), COYOTE (thermal mechanics), PRONTO3D (large deformation nonlinear mechanics), MPSalsa (chemically-reacting flows), ChiliSPICE (circuit modeling), GOMA (moving-boundary fluid flows), and ALEGRA and CTH (shock physics). By using these simulations as virtual prototypes, designs can be modified within the computer to achieve goals of:

- Minimizing weight, cost, or defects;
- Limiting critical temperature, stress, vibration, or other responses; or
- Maximizing performance, reliability, throughput, agility, or robustness.

A systematic, rapid method of determining these optimal solutions leads to better designs and reduces dependence on prototypes and testing, which shortens design cycles and lowers development costs.




*DAKOTA optimizes models of weapon components using Sandia software such as PRONTO3D and SALINAS. A comparison showing safety margin contours for an initial electronics package design (left), and the optimized design (right) is shown. The initial design violated allowable response levels by a factor of 2, whereas the optimized design removed all violations and still met strict weight targets.*

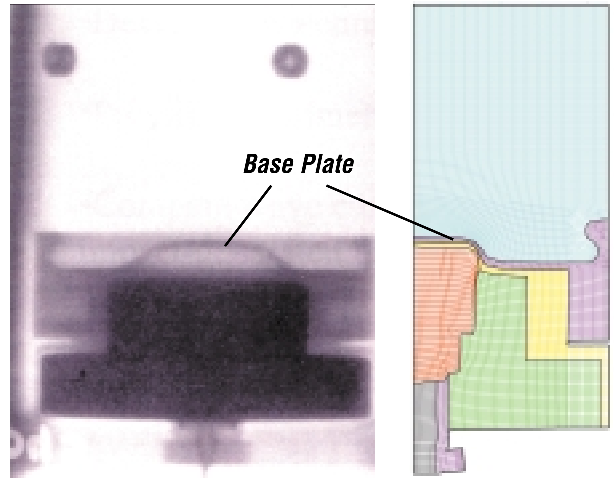
Recently, DAKOTA was used with SALINAS to optimize the design of an electronics package. This design must incorporate new components and still meet strict weight targets. To perform the optimization, a large 500,000 degree-of-freedom, finite-element model was used to resolve component responses in sufficient detail within the SALINAS analyses. In the operational environment, the initial design violated allowable response levels by a factor of 2. DAKOTA optimized this design and successfully eliminated all response violations while remaining within the strict weight budget.

To solve the problem in a tractable time frame, DAKOTA relied on massively parallel processing. DAKOTA and SALINAS together utilized 2,560 processors of Sandia's TeraFLOPS computer, accomplishing in four days what would have taken a single desktop computer more than 10 years to complete.

In another application, the weight of a radar load spreader plate was minimized while meeting structural response criteria under axial impact loads (simulated with PRONTO3D). Parallel processing enabled DAKOTA to rapidly compute optimal designs for several competing plate reinforcement concepts. These solutions enabled informed decision-making and resulted in a final design that met all response criteria and reduced weight by 24%. This design was successfully validated in full-scale, rocket-rail tests and subsequently fielded in the Nation's stockpile.

*Candidate reinforcement concepts for a radar load spreader plate are shown. DAKOTA optimized each of these designs, allowing for rational comparison and informed down selection.*

Other important applications are focusing on neutron generator power supply, tube optics, and manufacturing fixture design; materials characterization for foam and epoxy encapsulants, energetic materials, and ferroelectrics; worst-case scenario identification for system components in abnormal environments; chemical vapor deposition reactor design for operational profitability; and optimized explosive charge configurations for demolitions use. In addition, several U.S. industry partners also use the software. For example, members of the Coating and Related Manufacturing Processes Consortium are applying DAKOTA to optimize fluid flows, and Goodyear Tire & Rubber Company is using DAKOTA to optimize tire profiles.




*DAKOTA's solution schemes extend beyond design optimization. Shown here is a parameter estimation application in which the goal is to minimize discrepancy between test results and analysis predictions. Motion of the neutron generator power supply base plate is the critical phenomenon of interest.*

DAKOTA also provides a platform for research and development of advanced computational methods. Current research programs are focused on increasing the robustness and efficiency of systems analyses for computationally complex engineering problems. This work includes:

- Multilevel parallel computing,
- Mixed integer nonlinear programming,
- Surrogate-based optimization,
- Optimization under uncertainty, and
- Large-scale simultaneous analysis and design.

DAKOTA benefits from a close coupling of cross-disciplinary applications specialists with mathematicians and computer scientists. In particular, DAKOTA has strong ties with the SGOPT, PICO, DDACE, and OPT++ algorithm software libraries. These Sandia software packages provide a critical influx of the latest algorithmic developments. The result is state-of-the-art software products containing advanced mathematical algorithms that impact real-world engineering applications.

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